Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(2) (2021) 187-188
DOI: 10.22060/mej.2019.16574.6398

Age-Based Clustering Prognostics of Gas Turbines and Evaluation of the Proposed Method Robustness in Data Deficient Conditions

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ABSTRACT: The acceptable performance of the data-driven prognostics methods usually requires a large amount of data, therefore the performance usually is not desirable for small amount of data. The age clustering method multiplies the volume of the train data through observing data at multiple points. The advantage of the method is that it can be used for learning from a small set of data. The proposed approach is integratable with existing prediction methods and improves the accuracy of their result significantly. In this article, the ABC prognosis framework is described, its effectiveness for prognosis in normal conditions is illustrated in a case study on turbofan engines and a comparison with existing results on the same data is made. The paper continues with a study on the robustness of the proposed method under limited data conditions. The prognosis accuracy is compared for the case study in various conditions of available train data. The results emphasize (1) the efficiency of the method compared to other existing approaches in normally rich data condition and (2) the robustness of the results under limited data condition.

Review History:
Received: Jun. 18, 2019
Revised: Sep. 16, 2019
Accepted: Nov. 05, 2019
Available Online: Dec. 04, 2019

Keywords:
Prognosis and health management
Reliability
Limited data
Remaining useful life estimation

1. INTRODUCTION

The Prognostics and Health Management (PHM) techniques mainly are classified into three types: data-driven, model-based and hybrid approaches. In this paper, data-driven methods are considered. From another view, the prognosis methods are divided into regular methods and robust methods. A regular prognosis method results are acceptable only when rich data are available, otherwise, the results are unreliable. On the other side, the robust methods estimations are acceptable despite the lack of rich data. In this paper, the main objective is to propose a robust prognostic method in case of small data and to investigate its performance with a study case (2008 Prognostic Health Management Challenge data) [1, 2].

2. LAYOUT OF THE STUDY

2.1. Data Description

To illustrate the outcomes of this method on prognostics and health monitoring, a case study on turbofan engines from NASA's prognostics Information Repository is performed. The engine diagram in Fig. 1 shows the main components of the aircraft gas turbine engine model. The engine data consisting of 21 measurements are measured during every flight cycle. In the dataset, multiple units operate until failure occurs, providing a training set. The other units run to different levels of destruction, forming a test set. The challenge is to predict the Remaining Useful Life (RUL) of test units.

2.2. The Age-Based Clustering Prognostic Framework

A prognostics framework based on age clustering is developed. RUL estimation is accomplished through the age clustering of the engines and subsequently construction of a specific prediction module for each cluster. In the first step, the age distribution of the test set is determined and the set is divided into n groups. In the second phase, n predicate modules are constructed for n different age groups. In the second phase, observation of the training data is repeated several times and the units with lives shorter than the related observation point are omitted. Afterward, data of remained units is processed and vectors of Health Indicator Features (HIF) are produced in each reproduction. In the third phase, the prediction modules could be created by typical methods like regression, RVM or ANN. In the final stage, the RUL of each test engine is estimated based on its base age. For this purpose, depending on the base-age of the engine, the relevant group is first selected. Subsequently, the HIF is extracted and inputted to the relevant prediction module and the engine RUL is estimated.

3. RESULTS AND DISCUSSION

In this section, four tests are performed with 50%, 30%,

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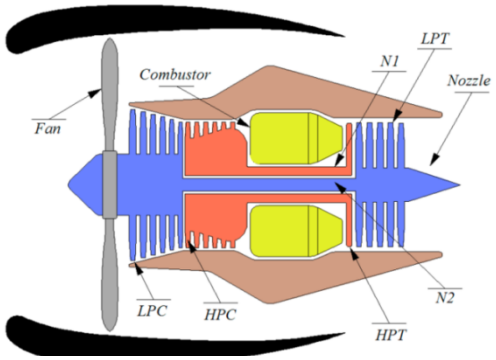

Fig. 1. Simplified diagram of the gas turbine engine [3]

20%, and 10% of train data. A comparison of prognosis measures for different sizes of train data is indicated in Fig. 2.

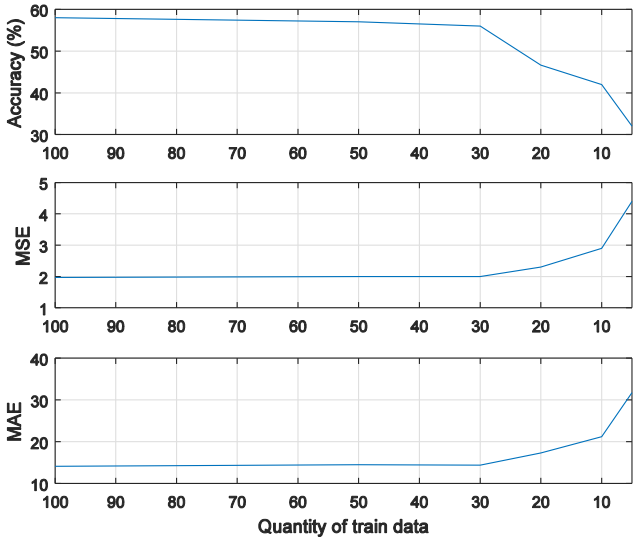

Fig. 2. Comparison of prognosis measures for different sizes of train data

4.CONCLUSION

In this paper, a novel prognostic algorithm is proposed. The main advantages of the proposed method are: (1) Easy to design, (2) Integrability with available prognosis methods, (3) Accuracy and Robustness.

A case study shows that:

1) The results of this method were improved compared to other conventional methods (71 % accuracy)

2) In the limited data condition, a comparison of the results of a different number of training data showed that the accuracy of the life prediction algorithm did not decrease significantly even by using 30% of the initial data. Afterward, the prediction accuracy decreased slightly, so that when the number of training data was reduced by 90%, the prediction accuracy decreased by 16% and the prediction accuracy decreased by 26% for a 95% reduction of the training data.

In the final step, more cases were tested and the results of the life prediction algorithm were evaluated using a small number of training data (10 motors). The results of this study showed that the age-based clustering method is a strong predictor of life under normal conditions. In addition, under limited circumstances, the information is also somewhat robust.

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HOW TO CITE THIS ARTICLE

A. Mahmoodian, M. Durali, M. Saadat, Age-Based Clustering Prognostics of Gas Turbines and Evaluation of the Proposed Method Robustness in Data Deficient Conditions, Amirkabir J. Mech. Eng., 53(2) (2021) 178-188.

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